



Secure Autonomous Automated Scheduling (SAAS) Phase 1 Final Report

Rev 1.1

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Prepared under Contract NNC07CB54C

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Space Administration

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Level of Review: This material has been technically reviewed by NASA technical management.

Available from

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Contents

1.0 Introduction	1
1.1 SAAS Phase 1 Demonstration Objective.....	1
1.2 Scope.....	2
2.0 GRC VMOC System Description	2
2.1 SAAS Phase 1 Network Architecture	2
2.2 Software Architecture	2
2.2.1 SAAS Information Flow	2
2.2.2 Information Flow Description.....	5
2.2.3 GRC VMOC Applications/Components	6
3.0 SAAS-Phase 1 Demonstrated Capabilities.....	11
3.1 GRC SAAS VMOC Applications/Interfaces	11
3.2 Other VMOC Capabilities Utilized.....	11
4.0 Recommendations	11
4.1 Continue SAAS Project Phases 2–4.....	11
4.2 Migrate TLM VMOC Capability to the GRC SAAS VMOC.....	11
5.0 Acronyms	12

List of Tables

TABLE 1.—INFORMATION FLOW DESCRIPTION.....	5
--------------------------------------------	---

List of Figures

Figure 1.—GRC VMOC System (for reference only).....	2
Figure 2.—SAAS-Phase 1 Demonstration Architecture.....	3
Figure 3.—SAAS Information Flow.....	4
Figure 4.—GRC SAAS VMOC Structure.	6
Figure 5.—GRC SAAS VMOC Main Page.....	7
Figure 6.—GRC SAAS VMOC Tactical Earthquake Admin Page.	8
Figure 7.—GRC SAAS VMOC Earthquake Tasks Page.....	8
Figure 8.—GRC SAAS VMOC UKDMC Collection Management.	9
Figure 9.—GRC SAAS VMOC UKDMC Contacts Page.	10
Figure 10.—GRC SAAS VMOC UKDMC Dashboard Page.....	10

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1.0 Introduction

1.1 SAAS Phase 1 Demonstration Objective

The Secure Autonomous Automated Scheduling (SAAS) project objective is to monitor the United States Geological Survey (USGS) earthquake notification system, automatically schedule an image acquisition of the target area via the Surrey Satellite Technology Ltd (SSTL), United Kingdom Disaster Monitoring Constellation-1 (UKDMC-1) satellite and download the acquired image to the General Dynamics (GD) developed Virtual Mission Operation Center (VMOC) at NASA's Glenn Research Center (GRC) for access by SAAS VMOC users. The aim is to reduce the time between notification and availability of the image by using multiple ground stations with both schedule upload and payload download capability as well as demonstrate the ability to perform SAAS of on-orbit assets, triggered by available sensor webs.

The SAAS project is to be developed in a phased approach based on initial utilization of the SSTL ground station and Mission Planning System (MPS) web services interface, escalating to the utilization of additional United Satellite Network (USN) ground stations located in Alaska, Hawaii, and Australia for both schedule upload and image download. The SAAS Project phases are:

- Phase 1: VMOC requests imaging opportunities from a simulated SSTL MPS via web service. The result is a valid schedule that is not acted upon. Tasking is simulated and a substitute raw image file will be made available via FTP for retrieval by the GRC VMOC. A further service will be made available for the VMOC to process the raw image to a single co-registered Tiff image. This processing service will apply across all four Phases.
- Phase 2: VMOC requests imaging opportunities from the live SSTL MPS via web service, subject to availability, tasking the UK-DMC-1 through SSTL's ground station to acquire the raw image file which will be downloaded to SSTL and made available via FTP.
- Phase 3: VMOC requests imaging opportunities from SSTL MPS via web service identifying the ground station to receive the download image, subject to availability. VMOC will task UK-DMC-1 through SSTL's ground station to acquire the raw image file. This will be broadcast from UK-DMC-1 to the identified ground station and made available via FTP.
- Phase 4: VMOC requests imaging opportunities from SSTL MPS via web service identifying the individual ground station to upload the schedule and potentially a different ground station to receive the broadcast download image, subject to availability. VMOC will upload the schedule file to UK-DMC-1 through the previously identified U/L ground station to acquire the raw image file. This will be transmitted from UKDMC-1 to the identified D/L ground station and made available via FTP.

For all phases of the SAAS project, the GRC VMOC provides the interface with the USGS earthquake web site for triggering of a SAAS of the UKDMC-1 satellite and provides the SAAS user interface for accessing the resultant imagery from the satellite.



Figure 1.—GRC VMOC System (for reference only).

1.2 Scope

This report provides a system and software description of the GRC VMOC developed for SAAS-Phase 1 and identifies the interfaces and capabilities demonstrated. In addition, the report provides recommendations for the continuation of the additional phases of the SAAS project.

2.0 GRC VMOC System Description

The SAAS demonstration Virtual Mission Operations Center (VMOC) is a system that consists of a Mission VMOC utilized for Command and Control, Space Situational Awareness (SSA) and Information Management.

The system, shown in Figure 1 for reference, is implemented as a rack-mounted chassis that houses modules interconnected through a standard internet connection. The computer interfaces to other platforms and equipment via standard connectors and cabling. The physical system resides at Glenn Research Center (GRC) in Cleveland Ohio and has connection via the Internet to field users.

2.1 SAAS Phase 1 Network Architecture

The network architecture shown Figure 2 was used during the SAAS Phase 1 demonstration. The GRC VMOC and TLM Server, SSTL Ground Station/MPS, USN Ground Station Planning System and USGS web sites all communicate over the open Internet, protected by Firewalls/Gateways at each of location. The SAAS Clients all interface the GRC SAAS VMOC web site to interact with the SAAS system.

2.2 Software Architecture

2.2.1 SAAS Information Flow

The information flow for the SAAS system is shown in Figure 3. The data paths allow users to access the system from anywhere that an Internet connection is located.

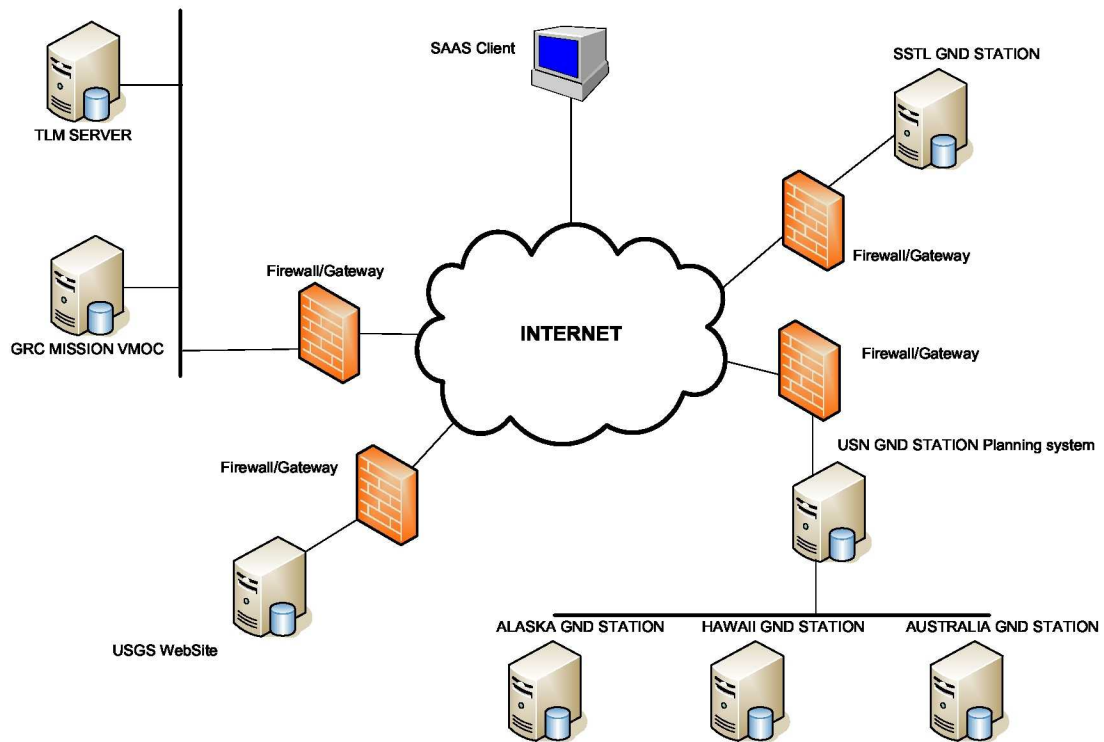


Figure 2.—SAAS-Phase 1 Demonstration Architecture.

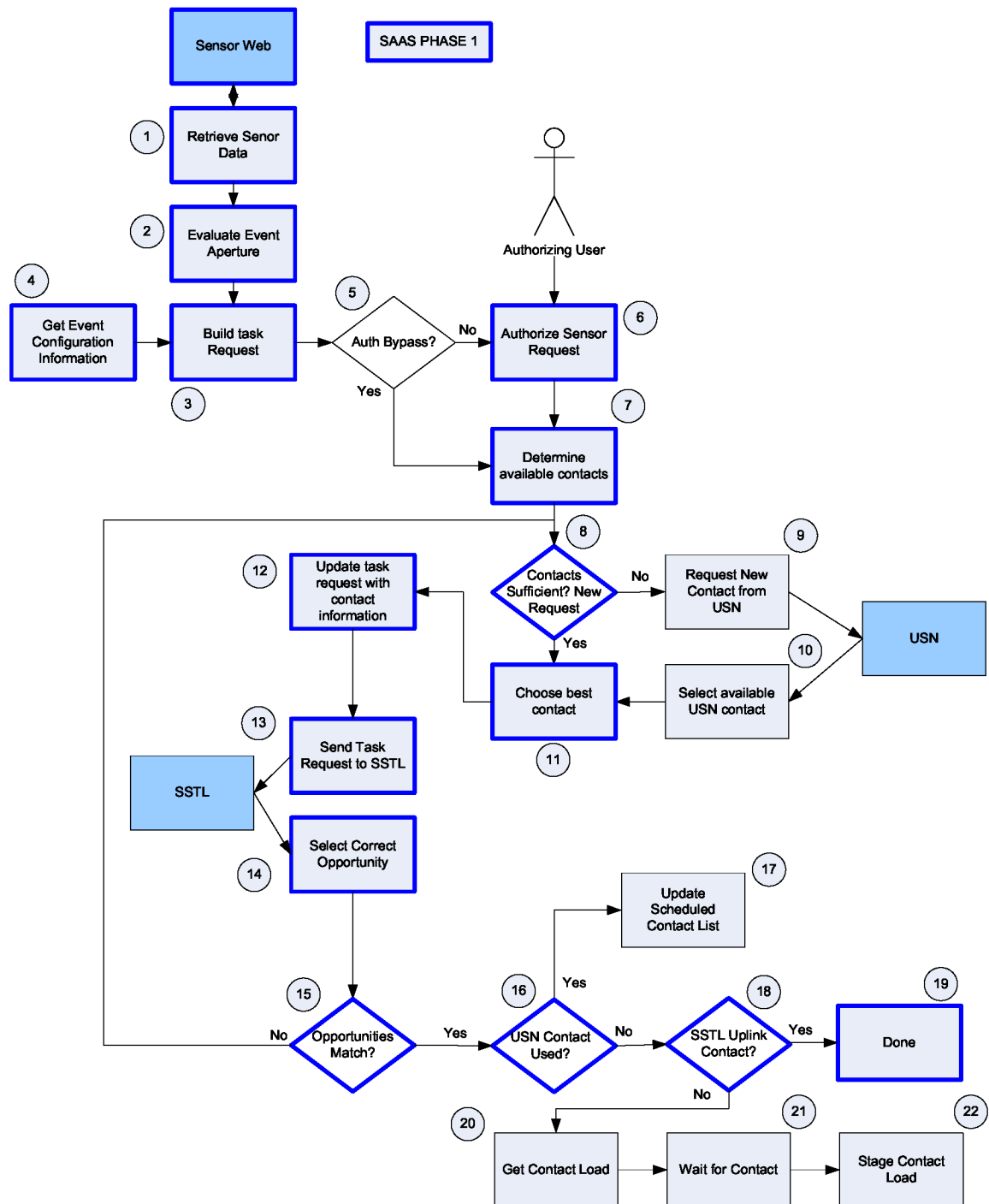


Figure 3.—SAAS Information Flow.

2.2.2 Information Flow Description

TABLE 1.—INFORMATION FLOW DESCRIPTION

Step	Title	Description
1	Retrieve sensor data	The VMOC Tactical App retrieves earthquake events. Obtains magnitude, location, time of the event, and the depth of quake from USGS web site. Poll the web page every 15 min (URL for retrieving the data is configurable as “USGSURL” in the Tactical App).
2	Evaluate event aperture	The VMOC Tactical App scrubs the earthquake events down to events above a certain Richter scale magnitude to be recorded (“MagnitudeToRecord” parameter in the Tactical Admin App) and above another magnitude to be tasked (“MagnitudeToTask” parameter in the Tactical Admin App).
3	Build task request	The VMOC Tactical App combines the earthquake data and other necessary provided by the VMOC Mission App to complete a task request for submission to the VMOC Mission App.
4	Get event configuration information	The VMOC Tactical App retrieves additional information needed to complete a task request from the VMOC Mission App.
5	Authorization bypass?	Based on the severity of the event, the VMOC Tactical App can be configured to wait or bypass task authorization.
6	Authorize sensor request	The VMOC Mission App provides a user interface for an authorizing user to select which earthquake imaging tasks to submit for execution.
7	Determine available contacts	The VMOC Mission App collects all currently scheduled ground station contacts. (every pass between UKDMC-1 and SSTL and only contacts that the VMOC has scheduled with USN).
8	Contacts sufficient? Or new request	All of the potential contacts are analyzed by the VMOC Mission App to determine which of the contact sets are sufficient to proceed and submit to the SSTL MPS (Considerations for “free”/paid (Service Agreement) contacts, best geometric conditions, time delay necessary to schedule new contacts, and necessity for multiple contacts should be used in the analysis). If there are no sufficient contacts available a new contact request is sent to USN.
9	Request new contact from USN	The VMOC Mission App sends a contact request to USN (interface TBD).
10	Select available USN contact	Select a set of usable contacts from the USN provided list of potential contacts (interface TBD).
11	Choose best contact	The VMOC Mission App selects the best contact from all usable/scheduled contacts.
12	Update task request with contact information	The VMOC Mission App adds the up/down link contact information to the task request.
13	Send task request to SSTL	The VMOC Mission App sends the Task Request to SSTL.
14	Select correct opportunity	The VMOC Mission App analyzes the list of potential tasking opportunities for an opportunity which matches an available scheduled contact set.
15	Opportunities match?	If, in the previous step, there are no tasking opportunities that match up with available scheduled contact sets, the process is repeated for a match.
16	USN contact used?	If a USN contact is to be used (up or down link) then the scheduled contact list needs to be updated. If not, proceed with determination whether staging of a contact load is necessary.
17	Update scheduled contact list	Update the scheduled contact list.
18	SSTL uplink contact?	If SSTL is used for uplink, then SSTL will handle the contact load. If not an SSTL ground station upload, proceed with staging of a contact load.
19	Done	VMOC process stops for SSTL uplink contacts.
21	Get contact load	The Mission VMOC App receives the uplink contact Load from SSTL.
22	Wait for contacts	The Mission VMOC App waits, as necessary, to stage the uplink contact load.
23	Stage contact load	Stage (transfer) the uplink contact load to the appropriate USN ground station.

2.2.3 GRC VMOC Applications/Components

The GRC SAAS VMOC (Fig. 4) consists of a five Adobe ColdFusion applications (Admin, Tactical, Mission, USN Ground and SSTL Ground Apps) contained within a web site container. Each application interfaces with all other apps and the outside world via Application Program Interfaces (API's) and each appropriate application provides a User Interface (UI) via the web site container to the SAAS VMOC user (not all UI's shown for clarity). The Tactical and Mission Applications also interface with AGI STK models for necessary satellite, sensor, target and ground station contact information's.

The main GRC SAAS VMOC page (Fig. 5) provides the user with a hierarchical menu structure to access each of the SAAS VMOC applications (that have User Interfaces). The main page also provides a status of the VMOC applications and VMOC connections and a list of current users online.

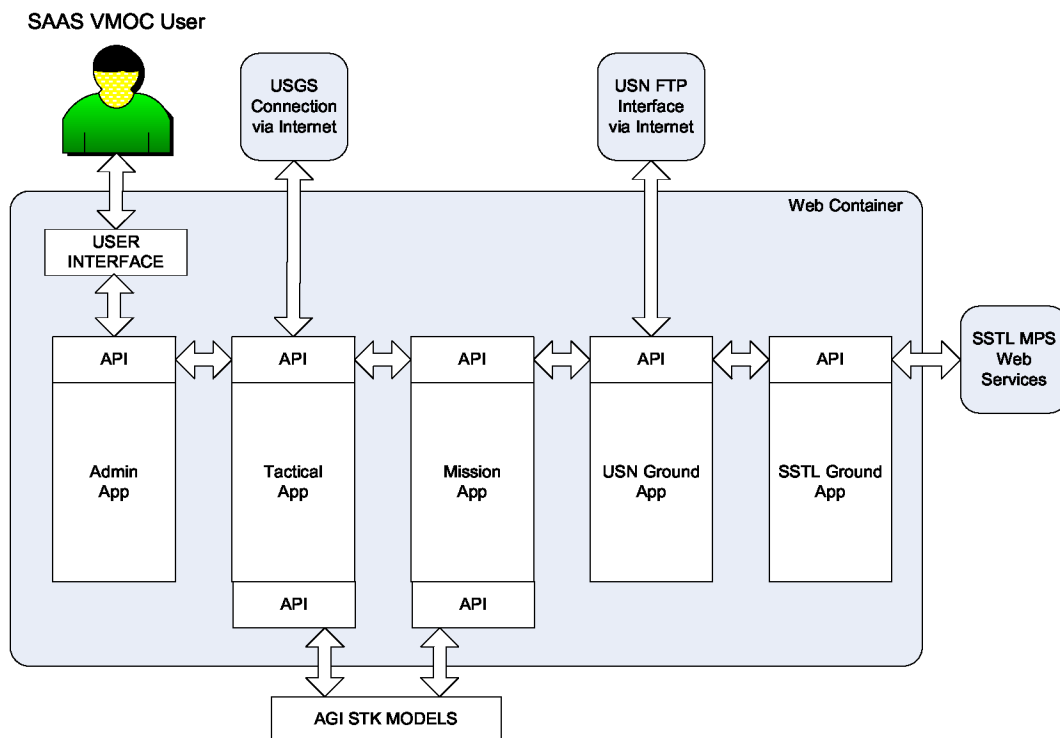


Figure 4.—GRC SAAS VMOC Structure.

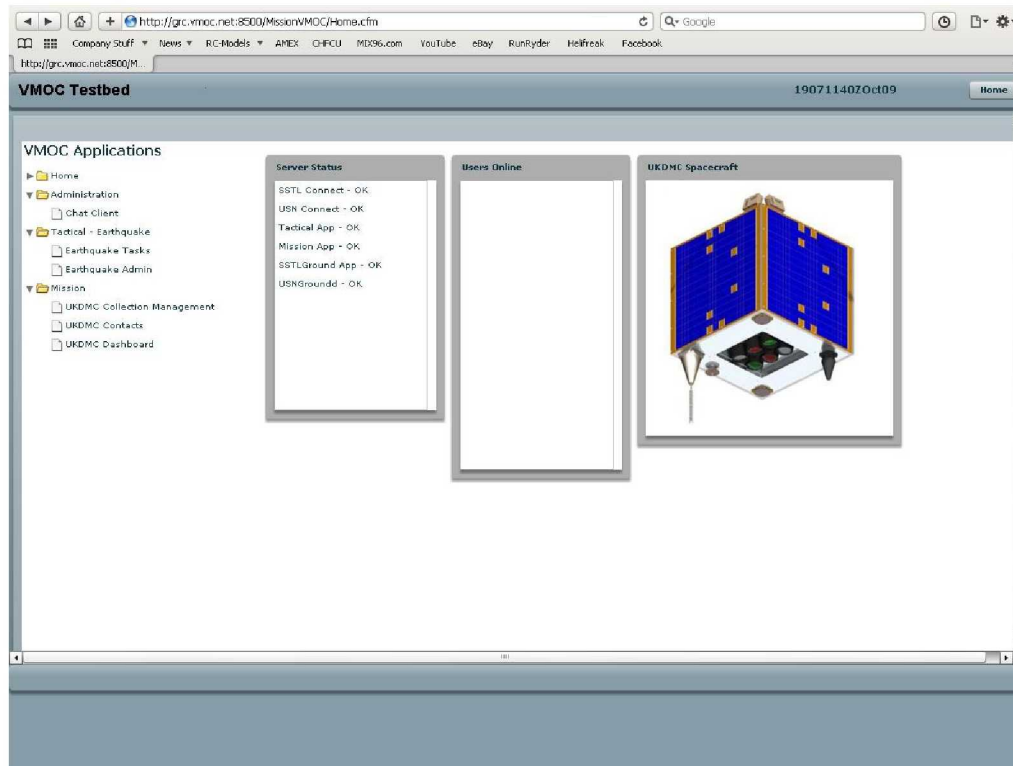


Figure 5.—GRC SAAS VMOC Main Page.

2.2.3.1 Administration Application

In the current GRC SAAS VMOC, demonstrated for Phase 1, the Administration application provides an online user chat capability (Chat Client). With future development (SAAS Phases 2-4) this application will provide the capability to manage the configuration settings for add-on applications providing the SAAS VMOC with additional capabilities.

2.2.3.2 Tactical Application

The Tactical Application in the current GRC SAAS VMOC, manages the retrieval of earthquake data from the USGS web site and constructs imaging task requests for selected earthquake events which are passed to the Mission Application for further processing. The Tactical Application provides two User Interfaces: The “Earthquake Tasks” and “Earthquake Admin” interface.

The Earthquake Admin interface shown in Figure 6, provides the user with the ability to configure the parameters for selecting earthquake events of interest, as described in the information flow earlier.

The Earthquake Tasks interface shown in Figure 7, provides the user with a list of all earthquake events collected based on the settings defined in the Earthquake Admin interface. The Earthquake Tasks interface also shows a list of all of the task created by and submitted to the Mission Application for further processing. Earthquake events and/or tasks selected in each of the lists are displayed on a map along with the event information.

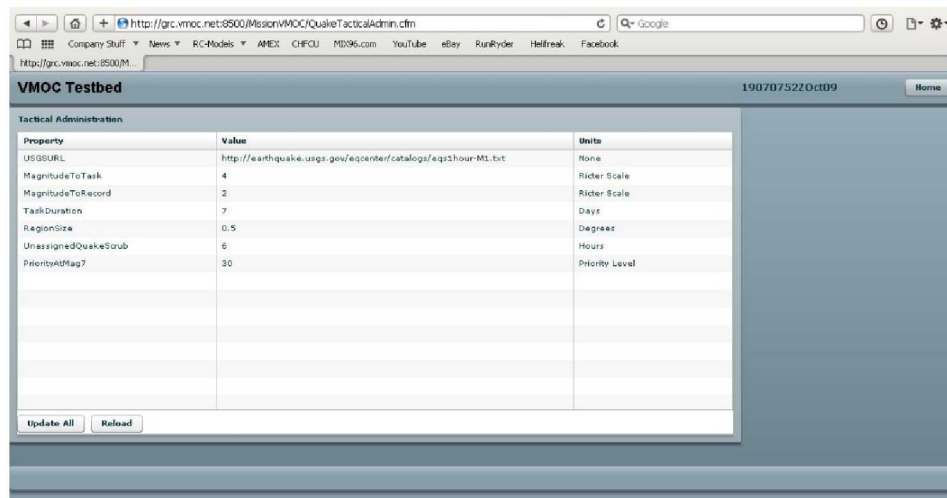


Figure 6.—GRC SAAS VMOC Tactical Earthquake Admin Page.

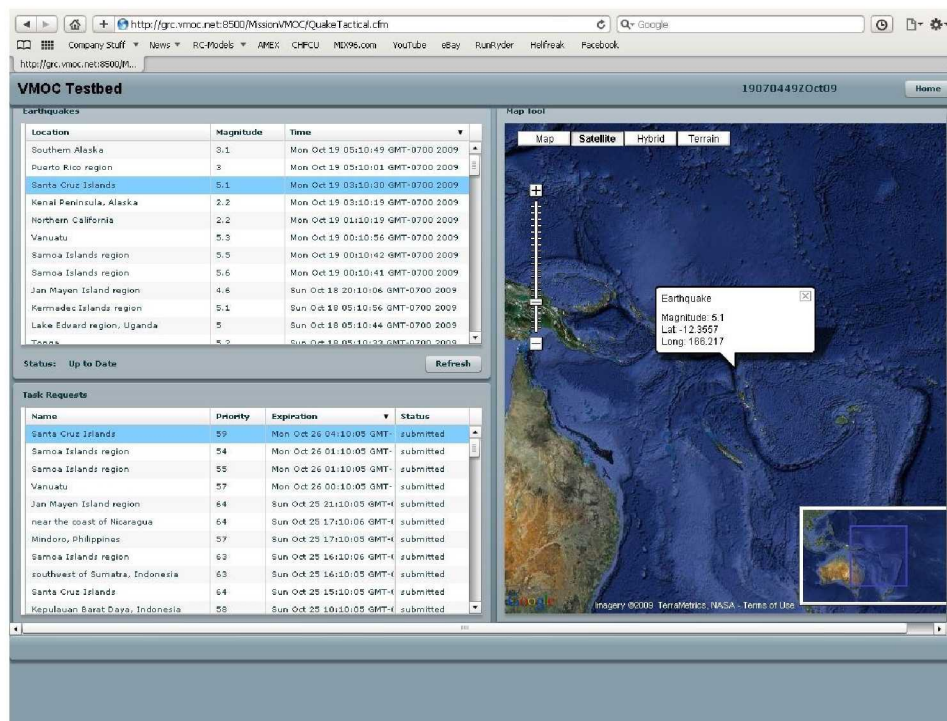


Figure 7.—GRC SAAS VMOC Earthquake Tasks Page.

2.2.3.3 Mission Application

The Tactical Application in the current GRC SAAS VMOC, analyzes all potential image task requests and compares the imaging opportunities with potential up/down link opportunities using the available ground stations. During this process, it submits scheduling requests, including the ground stations to be used, to the SSTL MPS. The SSTL MPS provides the Mission App with opportunities for imaging. The Mission App repeats this process until it determines an optimum set of up/downlink contacts and imaging opportunities that are executable. The Mission Application provides three User Interfaces: “UKDMC Collection Management,” “UKDMC Contacts” and “UKDMC Dashboard”.

The UKDMC Collection Management Interface, shown in Figure 8, provides the user with a list of all potential imaging task request for submission and allows the user to “authorize” the task request and subsequent image collection (select “Submit Request”).

With the fully developed GRC SAAS VMOC, the imaging task request would be sent to SSTL for execution, the uplink contact load would be provided by SSTL to the VMOC and the VMOC would stage the load to the appropriate ground station. The image collection would be accomplished per the uplink load and the image downloaded to the selected downlink ground station and passed on to the VMOC and be available for SAAS User access. For the SAAS Phase 1 demonstration, the process was only accomplished to the point of submitting the imaging collection to SSTL.

The “UKDMC Contacts” user interface, shown in Figure 9, provides the SAAS user with the ability to determine upcoming contacts between selected ground stations and the UKDMC-1 satellite for planning purposes.

The “UKDMC Dashboard” user interface, shown in Figure 10, provides the SAAS user with the current position of the UKDMC-1 satellite for planning purposes.

The screenshot displays the VMOC Testbed web application. The browser address bar shows the URL: <http://gnc.vnoc.net:8500/MissionVMOC/QuakeMission.cfm>. The page title is "VMOC Testbed" and the date is "190717312Oct09".

The main content area is divided into two sections:

- Pending Task Requests from Earthquakes:** This section contains a table with columns for "Mission Opportunities", "Collect Time", and "LTIOV". The table lists various mission opportunities, including "Sunda Strait, Indonesia", "Tajikistan", "Tonga", "Vanuatu", "near the coast of Nicaragua", "near the east coast of Honshu, Japan", "northern Mid-Atlantic Ridge", "off the coast of Ecuador", "offshore Chiapas, Mexico", "offshore El Salvador", "south of the Kermadec Islands", "southeast of the Loyalty Islands", "southern Sumatra, Indonesia", "southwest of Sumatra, Indonesia", "UKDMC", "USN-AK", "SSTL", and "western Iran". The "SSTL" row is highlighted.
- Task Details / Submission:** This section displays the details for the selected task request. The details include:
 - Task Title: southwest of Sumatra, Indonesia
 - Task UUID: 6A136170-0568-A5FF-46D769E700CD00C7
 - Category: Imagery
 - Subcategory: Visual
 - Vehicle Used: UK-DMC
 - Ground Station Used: SSTL
 - Collection Start: Tue Oct 20 00:21:45 GMT-0700 2009
 - Collection Stop: Tue Oct 20 00:22:27 GMT-0700 2009
 - LTIOV: Tue Oct 20 05:33:28 GMT-0700 2009
 - Estimated Cost: TBD
 - Derived From: Eq ID: 2009mxb9
 - Time of Earthquake: Sun Oct 19 04:10:11 GMT-0700 2009
 - Magnitude: 4.7

A "Submit Request" button is located at the bottom right of the Task Details section.

Figure 8.—GRC SAAS VMOC UKDMC Collection Management.

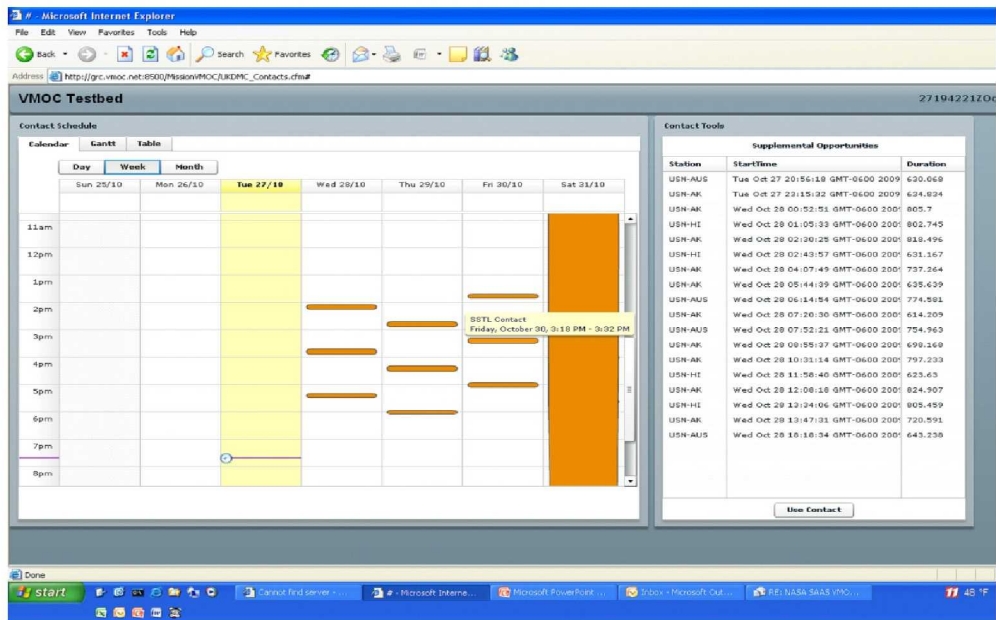


Figure 9.—GRC SAAS VMOC UKDMC Contacts Page.

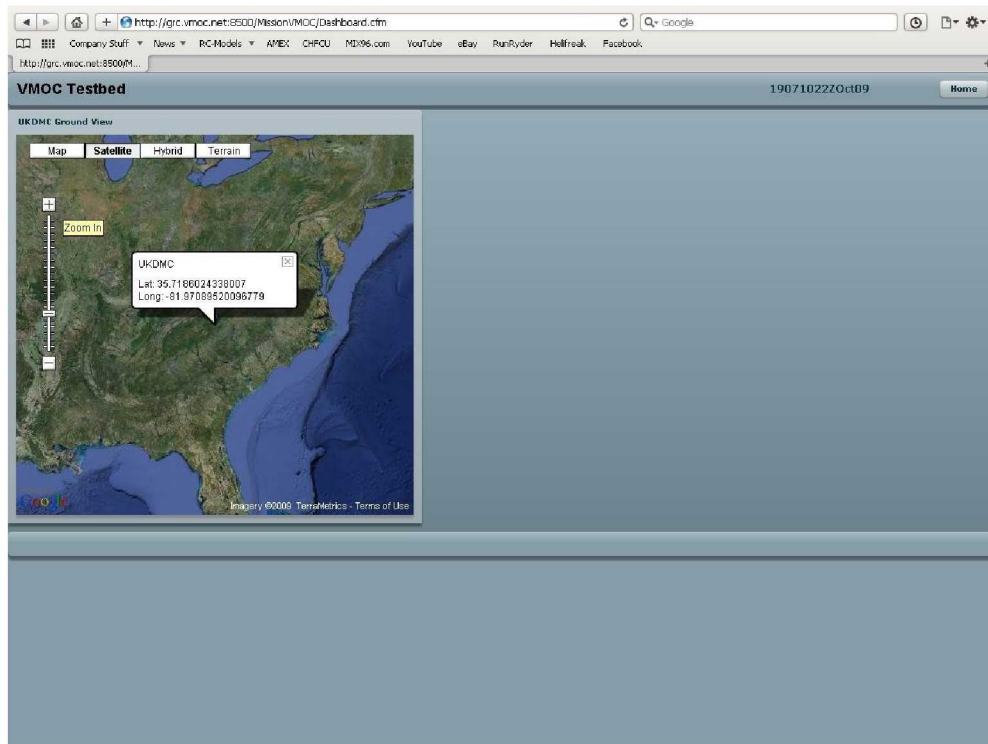


Figure 10.—GRC SAAS VMOC UKDMC Dashboard Page.

2.2.3.4 SSSL Ground Application

The SSSL Ground Application in the current GRC SAAS VMOC, does not have any User Interfaces and provides interfaces with the Mission Application for submission of imaging task requests to the SSSL MPS and retrieval of potential imaging opportunities from the SSSL MPS.

2.2.3.5 USN Ground Application

The USN Ground Application in the current GRC SAAS VMOC, does not have any User Interfaces and provides interfaces with the Mission Application for submission contact scheduling with the USN FTP scheduling interface. This interface was not utilized in SAAS Phase 1. The FTP interface was developed during Phase 1, but additional funding and additional USN ground station capabilities implemented before to support the additional SAAS project phases.

3.0 SAAS-Phase 1 Demonstrated Capabilities

3.1 GRC SAAS VMOC Applications/Interfaces

The GRC SAAS VMOC Administration, Tactical, Mission and SSSL applications were all exercised during a SAAS Phase 1 demonstration in July 2009. Selected earthquake events (as defined in the Earthquake Admin Interface) were successfully collected and presented to the user via the Earthquake Tasks interface. Imaging task requests were automatically created by the Mission Application, including ground station up/down link contact information. The Mission Application successfully negotiated with the SSSL MPS and determined an optimum imaging collection and up/down link contact tasking. These collection opportunities were presented to the user via the “UKDMC Collection Management” interface, allowing the SAAS user to “authorize” collections for execution. During the Phase 1 demonstration, actual uplink load contacts, imaging collections and downlink contacts were not performed. All other user interfaces were also successfully demonstrated.

3.2 Other VMOC Capabilities Utilized

In addition to the SAAS Phase 1 demonstration of the GRC SAAS VMOC capabilities, other existing VMOC capabilities were utilized to support USN Ground station troubleshooting. The original GRC VMOC, was utilized to both provide UKDMC-1 to Ground station contact information and also to verify successful telemetry downlinks.

4.0 Recommendations

4.1 Continue SAAS Project Phases 2–4

With the successful demonstration of SAAS of imaging collections during the Phase 1 demonstration, it is recommended that the development continue with the SAAS project to include actual collection and downlink of images via first the SSSL ground station (Phase 2), then downlink via USN ground stations (Phase 3) and final both uplink load and downlink via any available ground stations (Phase 3).

Follow on discussions with the Operationally Responsive Space (ORS) Office should continue to explore the synergy between NASA’s way ahead and the ORS Office. Of particular interest would be the VMOC to Goddard Space Flight Center (GSFC) Mission Services Evolution Center (GMSEC) interface.

4.2 Migrate TLM VMOC Capability to the GRC SAAS VMOC

Recommend that the capability to receive and display UKDMC satellite telemetry, available on the original GRC VMOC, be implemented on the current GRC SAAS VMOC.

5.0 Acronyms

AGI	Analytical Graphics, Inc.
FTP	File Transfer Protocol
GRC	Glenn Research Center
GMSEC	Goddard Mission Services Evolution Center
MPS	Mission Planning System
SAAS	Secure Automated Autonomous Scheduling
SSA	Space Situational Awareness
SSTL	Surrey Satellite Technology Ltd.
STK	Satellite Tool Kit
UKDMC-1	United Kingdom Disaster Monitoring Constellation-1
USGS	United States Geographical Survey
USN	United Space Network
VMOC	Virtual Mission Operations Center

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188		
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1. REPORT DATE (DD-MM-YYYY) 01-03-2010		2. REPORT TYPE Final Contractor Report		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Secure Autonomous Automated Scheduling (SAAS) Phase 1 Final Report Rev 1.1		5a. CONTRACT NUMBER NNC07CB54C			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S) Walke, Jon, G.; Dikeman, Larry; Sage, Stephen, P.; Miller, Eric, M.		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER WBS 387652.02.02.02.03			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) General Dynamics Advanced Information Systems		8. PERFORMING ORGANIZATION REPORT NUMBER E-17151			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001		10. SPONSORING/MONITOR'S ACRONYM(S) NASA			
		11. SPONSORING/MONITORING REPORT NUMBER NASA/CR-2010-216097			
12. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified-Unlimited Subject Categories: 17, 43, and 62 Available electronically at http://gltrs.grc.nasa.gov This publication is available from the NASA Center for AeroSpace Information, 443-757-5802					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT <p>This report describes network-centric operations, where a virtual mission operations center autonomously receives sensor triggers, and schedules space and ground assets using Internet-based technologies and service-oriented architectures. For proof-of-concept purposes, sensor triggers are received from the United States Geological Survey (USGS) to determine targets for space-based sensors. The Surrey Satellite Technology Limited (SSTL) Disaster Monitoring Constellation satellite, the UK-DMC, is used as the space-based sensor. The UK-DMC's availability is determined via machine-to-machine communications using SSTL's mission planning system. Access to/from the UK-DMC for tasking and sensor data is via SSTL's and Universal Space Network's (USN) ground assets. The availability and scheduling of USN's assets can also be performed autonomously via machine-to-machine communications. All communication, both on the ground and between ground and space, uses open Internet standards.</p>					
15. SUBJECT TERMS Network; Security; Communications; Satellite					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 19	19a. NAME OF RESPONSIBLE PERSON STI Help Desk (email: help@sti.nasa.gov)
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (include area code) 443-757-5802

